Coupled retrieval of water cloud and above-cloud aerosol properties using AirMSPI

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The Airborne Multiangle SpectroPolarimetric Imager (AirMSPI) has been flying aboard the NASA ER-2 high altitude aircraft since October 2010. AirMSPI acquires radiance and polarization data in bands centered at 355, 380, 445, 470*, 555, 660*, 865*, and 935 nm (the asterisk denotes polarimetric bands). In sweep mode, georectified images cover an area of 80–100 km (along track) by 10–25 km (across track) between ±66° off nadir, with a map-projected spatial resolution of 25 meters.

An optimization algorithm is developed to retrieve liquid water cloud properties including cloud optical depth (COD), droplet size distribution and cloud top height (CTH), and aerosol above cloud properties including aerosol optical depth (AOD), single scattering albedo and microphysical properties. The retrieval is composed of three major steps: (1) retrieval of an initial estimate of the mean droplet size distribution across the entire image of 80–100 km along-track by 10–25 km across-track from polarimetric cloudbow observations; (2) coupled retrieval of image-scale cloud and above-cloud aerosol properties by fitting the polarimetric data at all observation angles; and (3) iterative retrieval of pixel-scale COD and droplet size distribution by establishing relationships between COD and cloud droplet size and fitting the total radiance measurements. Our retrieval is tested using 134 AirMSPI datasets acquired during the NASA ORACLES field campaign in September 2016. The retrieved above-cloud AOD and CTH are compared to coincident HSRL-2 (NASA LaRC) data, and COD and droplet size distribution parameters (effective radius r_{eff} and effective variance v_{eff}) are compared to coincident RSP (NASA GISS) data. Mean absolute differences (MADs) between AirMSPI and HSRL-2 retrievals of above-cloud AOD at 532 nm and CTH are 0.03 and < 0.5 km, respectively. At RSP's footprint scale, MADs between RSP and AirMSPI retrievals of COD, r_{eff} and v_{eff} in the cloudbow area are 2.33, 0.69 μm and 0.020, respectively. Neglect of smoke aerosols above cloud leads to an underestimate of image-averaged COD by ~15%.

Preferred mode of presentation: Oral